

## **WARNING**

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# Charles Darwin University

Final Examination

Family Name					
Given Name/s					
Student Number					
Teaching Period	Semester 1, 2018				

ENG462 – Water Resources Engineering	DURATION	
	Reading Time:	10 minutes
	Writing Time:	180 minutes
INSTRUCTIONS TO CANDIDATES		
<ol style="list-style-type: none"> <li>1 Read all questions.</li> <li>2 Answer ALL questions using the Answer Booklet supplied.</li> <li>3 Ensure that your name and student number are clearly indicated on your Answer Booklet and at the top of this examination paper.</li> <li>4 Show all working (e.g., calculations and sketches).</li> <li>5 This exam constitutes 50 % of the total marks available for this Unit.</li> <li>6 Total marks available on this exam: 100.</li> <li>7 All questions are of equal value.</li> <li>8 Use dark blue, or black, ink.</li> </ol>		
EXAM CONDITIONS		
<p><u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.</p>		
This is a CLOSED BOOK examination		
Any non-programmable calculator is permitted		
No handwritten notes are permitted		
No dictionaries are permitted		
ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED	
No additional printed material is permitted	1 x 20 Page Book 1 x Scrap Paper Formula Sheet/s Graph Paper	

Semester 1, 2018

FINAL EXAMINATION  
ENG462 – Water Resources Engineering

Page 1 of 8

THIS EXAMINATION PAPER AND SUPPLIED MATERIALS ARE NOT PERMITTED TO BE REMOVED FROM ANY EXAMINATION VENUE IN ANY CIRCUMSTANCE. THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

THIS EXAMINATION IS PRINTED  
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- Q1 Two pipes with circular cross-sections are connected (in series) and used to transfer water between two storage tanks, which are open to the atmosphere. The vertical elevation difference between the free water surfaces in the tanks is 42 m. Details of the pipe system are given in Table Q1.

Table Q1 Pipe system parameters

Pipe identifier	Diameter (mm)	Length (m)	Friction factor $\lambda$
1.1	600	800	0.025
1.2	450	600	0.020

- (a) Determine the discharge through the pipe system (in  $\text{m}^3\text{s}^{-1}$ ).
- (b) Assess the effect of the leakage of 10 % of the volumetric flow rate from Pipe 1.2 (above) on your answer to Q1(a).
- (c) Summarise two possible ways in which the leakage in Q1(b), above, could be detected if the system in question were operating in a remote community location.

(10 marks)

(4 marks)

(6 marks)

**(Total: 20 marks)**

- Q2 The inflow to a reach of a river has been measured and recorded. The reach is 12.5 river km in length, and the water normally flows at an average velocity of  $0.8 \text{ m s}^{-1}$  in that reach. At a given time after a rainstorm occurring upstream of this reach of the river, and within its catchment area, there was a change in the observed water level in the reach. Part of the tabulated calculations used to predict the downstream outflow from the reach of this river, using the Muskingum method, is given in Table Q2. It may be assumed that the weighting factor  $x$  is 0.25.

Table Q2 River flow prediction data		
Time (h)	Inflow ( $\text{m}^3 \text{ s}^{-1}$ )	Outflow ( $\text{m}^3 \text{ s}^{-1}$ )
15	28.32	23.69
18	141.6	65.14
21	118.9	128.4
24	96.28	?

- a) Recommend, and justify, a value for the kinematic wave velocity (in  $\text{m s}^{-1}$ ). (2 marks)
- b) Using the value that you recommended in Q2(a) above, calculate the storage time constant for this reach of the river (in hours and minutes). (2 marks)
- c) Determine the predicted value of outflow from this reach of the river after 24 h. (10 marks)
- d) Flood levels are shown in Figure Q2(d) with river level data measured at a gauging station downstream of the reach of the river analysed in Q2(a). Suggest immediate measures to be enacted by Local Government, the Emergency Services, and the local water/sewerage, and energy utilities responsible for this remote township. (6 marks)

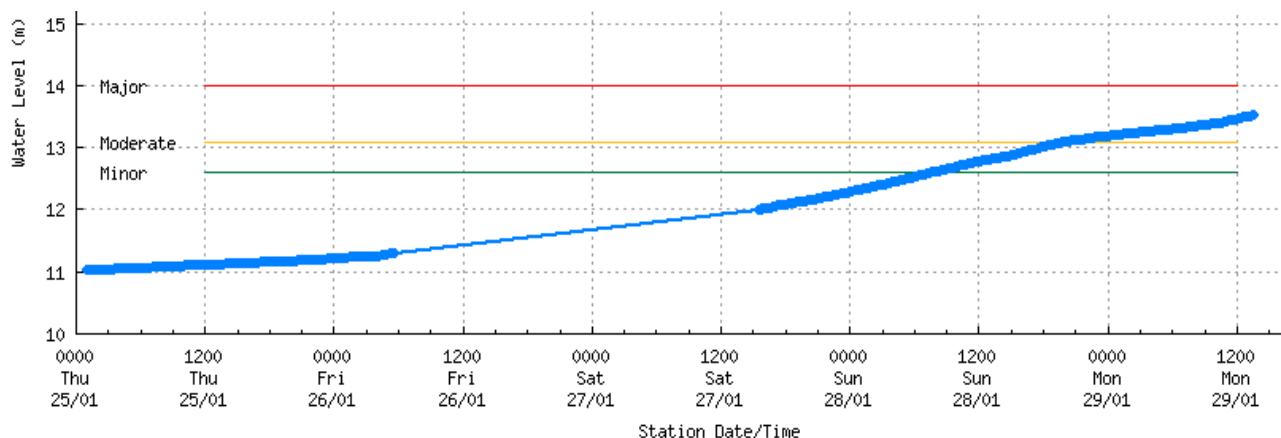


Figure Q2(d) Downstream river heights (flood conditions from 0600 Sunday 28 January, 2018)

(Australian Government Bureau of Meteorology (2018) Latest river heights for Daly River at Daly River Police Station. Station 514910, BoM, Melbourne, Australia. Available from: <http://www.bom.gov.au/fwo/IDD60322/IDD60322.514910.plt.shtml>. Last accessed: 29 January, 2018, image cropped to fit.)

**(Total: 20 marks)**

- Q3 Doppler wind, and rainfall, radar images from Berrimah, NT are provided in Figures Q3(a) and Q3(b). The wind data were sampled at 13:51 local time, and the rainfall data at 14:00 local time, on 29 January, 2018.

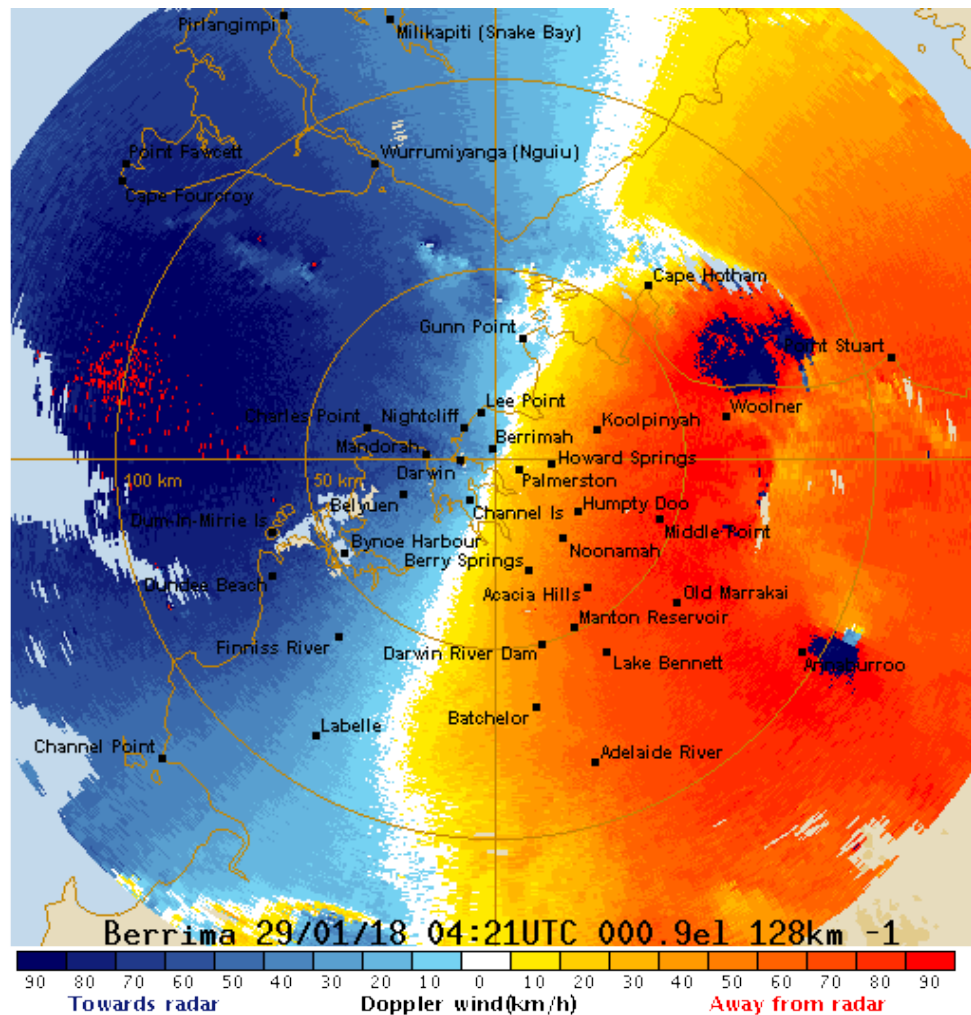


Figure Q3(a) Doppler wind radar data: Berrimah 29 January, 2018, chart radius 128 km.

(Australian Government Bureau of Meteorology (2018) 128 km Darwin (Berrimah) Doppler wind, BoM, Melbourne, Australia. Available from: <http://www.bom.gov.au/products/IDR633.shtml#skip>. Last accessed: 29 January, 2018.)

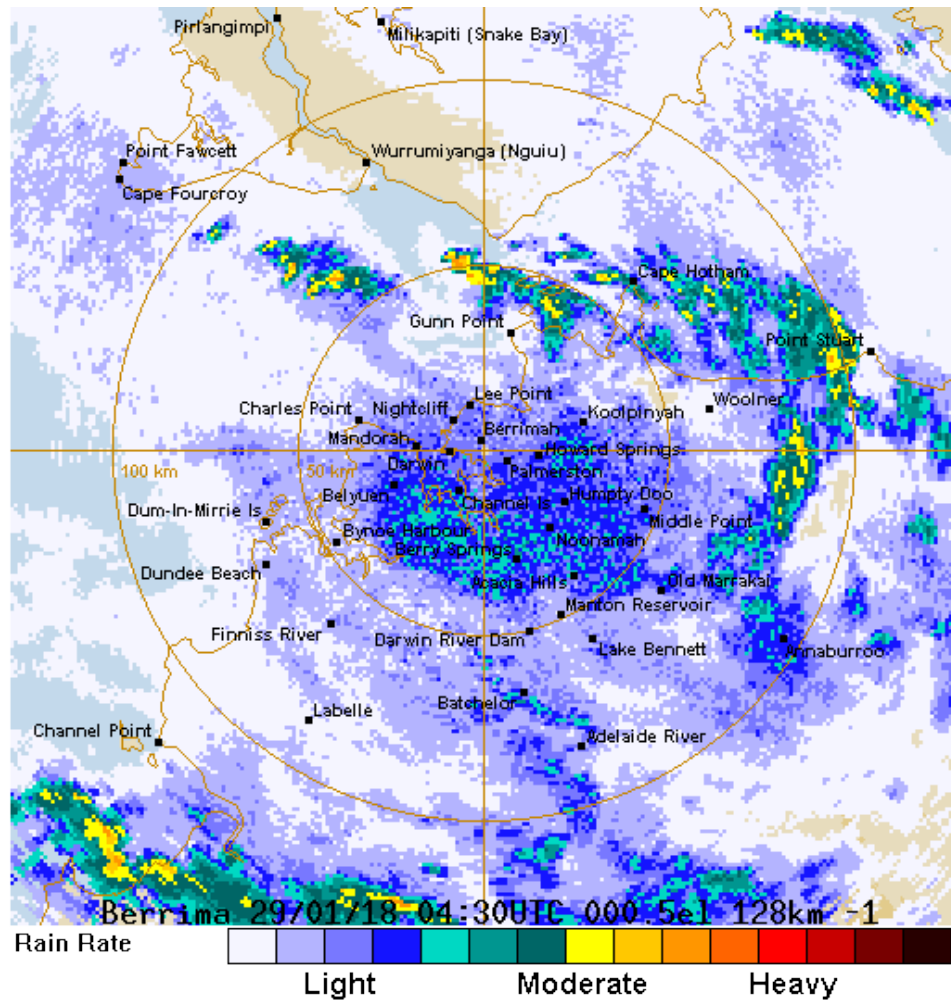


Figure Q3(b) Rainfall radar data: Berrimah 29 January, 2018, chart radius 128 km.

(Australian Government Bureau of Meteorology (2018) 128 km Darwin (Berrimah) Radar, BoM, Melbourne, Australia. Available from: <http://www.bom.gov.au/products/IDR633.shtml#skip>. Last accessed: 29 January, 2018.)

Explain what is indicated by the coloured regions in both Figures Q3(a) and Q3(b) and their significance with respect to future surface and ground water abstraction in that region of Australia's Northern Territory.

(20 marks)

**(Total: 20 marks)**

Q4 An unconfined aquifer has 22.45 m depth of fresh water (density  $1000 \text{ kg m}^{-3}$ ) overlying 30 m depth of saline water (density  $1004 \text{ kg m}^{-3}$ ). Two standpipe piezometers are installed in the aquifer such that the open section of Piezometer A is at a depth of 10 m below the water table, and the open section of Piezometer B is at a depth of 40 m below the water table.

- (a) Describe how the salinity of a water sample abstracted from the stratum below the unconfined aquifer would be measured.

(4 marks)

- (b) Assuming that there is no groundwater flow in the aquifer, and that the piezometers contain water of the same density as that surrounding the lower end of the piezometer, determine the vertical difference in height between the water levels in Piezometers A and B, and state which (if any) has the higher water level relative to the base of the aquifer.

(6 marks)

- (c) Now assuming that there *is* some three-dimensional groundwater flow in the aquifer, discuss the implications of the vertical injection of a well point, such as is used in hydraulic fracturing operations, through the aquifer to a depth of 2 km.

(10 marks)

**(Total: 20 marks)**



Q5 A rectangular, open, channel is 25 m wide and has a bed slope of 3.0 m per km. The Manning coefficient  $n$  for the sides, and bed, of the channel is 0.036.

- (a) If the discharge from the channel is  $45 \text{ m}^3 \text{ s}^{-1}$ , determine the normal depth of flow in the channel. Hint: the normal depth of flow is between 1.0 m and 1.2 m.

(10 marks)

- (b) Assess the effectiveness, and comment upon the drawbacks, of an eco-engineering approach to the design of such a channel as exemplified by that shown in Figure Q5(b).



Figure Q5(b) Eco-engineering approach to urban channel design, Singapore.

(Buurman J. (2017) ABC Waters in Singapore. [WaterPolicy.online](http://waterpolicy.online), Lee Kuan Yew School of Public Policy, National University of Singapore, Singapore. Available from: <http://waterpolicy.online/abc-waters-in-singapore/>. Last accessed: 30 January, 2018.)

(10 marks)

**(Total: 20 marks)**

# ENG462 WATER RESOURCES ENGINEERING

## FORMULAE AND DATA SHEET

Assume:                      Density of water                      = 1000 kg m<sup>-3</sup>                      (at 4 °C)  
                                  Kinematic viscosity of water                      = 1.14 mm<sup>2</sup> s<sup>-1</sup>                      (at 15 °C)  
                                   $\alpha$                       = 1.0

$$\nu = \frac{\mu}{\rho}$$

Temperature (°C)	Dynamic viscosity $\mu$ ( $\times 10^{-3}$ N s m <sup>-2</sup> )	Kinematic viscosity $\nu$ ( $\times 10^{-6}$ m <sup>2</sup> s <sup>-1</sup> )
5	1.519	1.519
10	1.307	1.307
20	1.002	1.004
30	0.798	0.801
40	0.653	0.658
50	0.547	0.553
60	0.467	0.475
70	0.404	0.413
80	0.355	0.365
90	0.315	0.326

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

$$Re = \frac{\rho V L}{\mu} = \frac{V L}{\nu}$$

$$Re = \frac{\rho V D}{\mu} = \frac{V D}{\nu}$$

$$Fr = \frac{V}{\sqrt{g \times y}}$$

$$h_f = \frac{\lambda L V^2}{2 g D}$$

$$\frac{1}{\sqrt{\lambda}} = -2 \times \log \left( \frac{k}{3.7 D} + \frac{5.1286}{Re^{0.89}} \right)$$

$$V = -2 \sqrt{2 g D \frac{h_f}{L}} \times \log \left( \frac{k}{3.7 D} + \frac{2.51 \nu}{D \sqrt{2 g D \frac{h_f}{L}}} \right)$$

$$\delta Q = - \frac{\Sigma(h_L)}{2 \times \Sigma\left(\frac{h_L}{Q}\right)}$$

$$K = \frac{\lambda \times L}{2 \times g \times D \times A^2} \quad (h_L = K \times |Q| \times Q)$$

$$V = \frac{1}{n} \times R^{\frac{2}{3}} \times S_0^{\frac{1}{2}}$$

$$Q = K \times A \times \frac{h_1 - h_2}{L}$$

$$Q_p = \frac{C_R C_V i}{0.36} \times A$$

$$t_c = 6.99 \times \left( \frac{n \times L}{i_e^{0.4} \times S_0^{0.3}} \right)^{0.6}$$

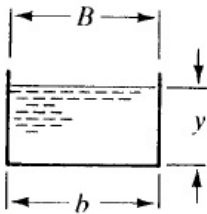
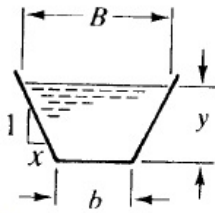
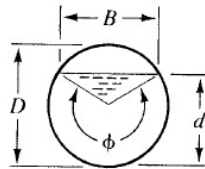
$$\frac{\delta y}{\delta x} = \frac{S_0 - S}{1 - \frac{V^2}{g y}} = \frac{S_0 - S}{1 - (Fr)^2}$$

$$\Delta x = \frac{\left( y_1 + \frac{V_1^2}{2 g} \right) - \left( y_2 + \frac{V_2^2}{2 g} \right)}{S - S_0}$$

Depth (m)	Area (m <sup>2</sup> )	P (m)	R (m)	Velocity (ms <sup>-1</sup> )	Mean velocity (ms <sup>-1</sup> )	Mean R (m)	S	x (m)
X	X	X	X	X				0
					X	X	X	
X	X	X	X	X				X
					X	X	X	
X	X	X	X	X				X
...								
...								

$$P_{\text{exceedance}} = 1 - (1 - p)^n$$

### Properties of common channel cross-sections

			
	Rectangle	Trapezoid	Circle
Area (A)	$b y$	$(b + xy) y$	$\frac{1}{8} (\phi - \sin \phi) D^2$
Wetted perimeter (P)	$b + 2y$	$b + 2y\sqrt{1 + x^2}$	$\frac{\phi D}{2}$
Top width (B)	$b$	$b + 2xy$	$\left( \sin \frac{\phi}{2} \right) D$
Hydraulic radius	$\frac{by}{b + 2y}$	$\frac{(b + xy) y}{b + 2y\sqrt{1 + x^2}}$	$\frac{1}{4} \left( 1 - \frac{\sin \phi}{\phi} \right) D$
Hydraulic mean depth ( $D_m$ )	$y$	$\frac{(b + xy) y}{b + 2xy}$	$\frac{1}{8} \left( \frac{\phi - \sin \phi}{\sin(1/2\phi)} \right) D$

$$S = K \times (x \times I + (1 - x) \times O)$$

$$O_2 = C_0 \times I_2 + C_1 \times I_1 + C_2 \times O_1$$

where  $C_0 = \frac{-Kx + 0.5 \Delta t}{K(1 - x) + 0.5 \Delta t}$

$$C_1 = \frac{Kx + 0.5 \Delta t}{K(1 - x) + 0.5 \Delta t}$$

$$C_2 = \frac{K(1 - x) - 0.5 \Delta t}{K(1 - x) + 0.5 \Delta t}$$

Groundwater volume flux (or specific discharge  $q$ ) is given by:

$$q = \frac{Q}{A}$$

where  $q$  = specific discharge ( $\text{ms}^{-1}$ );  
 $Q$  = discharge ( $\text{m}^3\text{s}^{-1}$ );  
 $A$  = area of rock through which water is flowing ( $\text{m}^2$ ).

Darcy's law (in terms of the specific discharge and the difference in head between the ends of a column):

$$q = \frac{Q}{A} = -K \times \frac{h_2 - h_1}{L}$$

